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Relationship of facial type and nasopalatine canal course

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1. Abstract

Objectives:

The aim of this study was to describe the course of the nasopalatine canal, the adjacent vertical bone quantity, and whether it might differ among vertical facial types using cone beam computed tomography (CBCT) scans.

Material and Methods:

Out of a consecutive sample collected from April 2008 to August 2012, only patient data depicting both upper and lower jaw completely were evaluated retrospectively. The linear measurements were taken on the respective midsagittal view perpendicular to the palate at the level of 1st molar/2nd premolar (5/6), 2nd premolar/1st premolar (4/5), and 1st premolar/canine (3/4). Screen-prints were used to measure the inclination of the nasopalatine canal in relation to the maxillary jaw base. Maxillary and mandibular divergence was assessed on rendered lateral cephalograms.

Results:

Out of 3869 consecutive patients, data from 398 patients met the inclusion criteria and could be extracted. The mean vertical bone was 4.09 millimeter at the 5/6 level, 5.22 mm at the 4/5 level and 3.14 mm at the 3/4 level, respectively. A statistically significant negative correlation exists between jaw divergence and the canal angulation with regard to the maxillary base. A statistically significant negative correlation exists between the canal angulation and vertical bone measurements at the 4/5 and 3/4 levels.

Conclusions:

Vertical bone volume is sufficient at 4/5 level for temporary anchorage devices (TAD) placement, and bares only a small risk for neuro-sensory impairment. However, the course of the nasopalatine canal is negatively correlated with the vertical skeletal facial pattern pointing to the fact that in hypodivergent patients a TAD might be placed in a more distal or paramedian region.

2. Introduction

2.1 Anchorage in orthodontics

Anchorage in orthodontics is one of the most important aspect and its management and control is essential for successful treatment results. Orthodontic anchorage was first described by Angle in 1907 (Angle 1907) and later denoted by Ottofy in 1923 (Ottofy 1923), where anchorage in orthodontics is defined as the nature and degree of resistance to displacement offered by an anatomic unit for the purpose of tooth movement.

While mostly the anchorage potential of the teeth and their periodontal ligament is used for treatment, other structures such as the perioral soft tissues (Osborn, et al. 1991), the gingiva, the lingual mandibular alveolar bone or the occipital bone and the neck might be used for anchorage purposes as well (Ferro, et al. 2004). Some of these anchorage devices, such as plates or extraoral appliances are dependent on patient’s compliance (Nanda & Kierl 1992). However, additional anchorage to provide extraoral and intraoral forces is visible and hence, compliance dependent, as well as associated with the risk of undesirable effects such as tipping of the occlusal plane, protrusion, gingival recession of mandibular incisors, and extrusion of teeth.

Implants, mini-screws, and ankylosed teeth, do not possess a normal periodontal ligament as they are in direct contact with bone (Wehrbein & Göllner 2009). As a consequence, these units don’t move when low-to-moderate orthodontic forces are applied (Hsieh, et al. 2008, Melsen & Lang 2001) and hence, may be used for "absolute anchorage" independent of patient compliance.

2.2 Evolution of palatal implants

In the evolution of implants, used for skeletal bone anchorage, Gainsforth and Higley in 1945 were first to insert vitallium screws and stainless steel wires in the ramus of dog mandibles in order to apply elastics to retract the canine (Gainsforth 1945). Later in development in 1969, based on applications in implant dentistry, blade implants were used for rubber band anchorage to retract teeth (Linkow 1969). As animal studies showed promising results for stability of osseointegrated titanium implants under orthodontic load, in 1988 endosseous implants were suggested for orthodontic anchorage purposes (De Pauw, et al. 1999, Turley, et al. 1988, Wehrbein & Diedrich 1993).

Based on these findings specially designed implants for palatal bone insertion of the maxilla were developed for anchoring purpose (Triaca et al. 1992) and initially the midsagittal palatal region has been postulated (Block & Hoffman 1995, Daskalogiannakis 2000, Wehrbein, et al. 1996).

The simplicity in use, minimal stress during surgical implant installation and removal, as well as the reliable success rates of palatal implants (Jung, et al. 2007, 2009, 2012a, Männchen & Schätzle 2008, Schätzle, et al. 2009a) are prerequisites for the high acceptance of this treatment modality by the orthodontic patients.

The most widely used orthodontic anchorage system is the Orthosytem® (Institut Straumann). This titanium implant has three distinct features (Fig. 1): a self-tapping endosseous body, 4.2 mm long and either 4.1 mm or 4.8 mm in diameter, designed to be inserted into bone, a smooth neck portion (4.8 mm in diameter and 1.8 mm in length) serving as the transmucosal part, and a trigonal head for orthodontic appliance fixation.

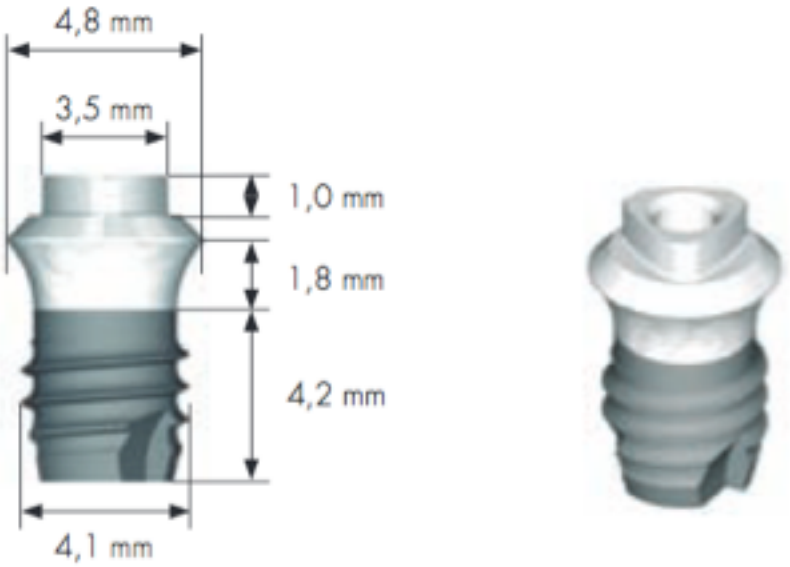

Fig. 1 Orthosytem®, made of pure titanium, is available in two different diameters. The endosseous part of the implant has SLA surface and is 4.2 mm long. The smooth neck of the implant is 1.8 mm high (Institut Straumann, Switzerland).

2.3 Anatomical considerations for TADs

There might be concerns regarding the achievement of primary stability of mid-palatal implants due to the late closure of the median suture and the limited bone thickness of the hard palate. In a histological evaluation Wehrbein and co-workers showed, that sufficient primary implant stability could be achieved in the mid-palatal anterior hard palate, where bone quality and bone availability is favourable for insertion (Wehrbein 2008). Nevertheless, routinely preoperative computed tomography for planning and diagnosis has been suggested by a number of authors to identify bone volume to therefore avoid complications, such as perforation of the nasal floor or damage of the incisory nerve (Bantleon, et al. 2002, Bernhart, et al. 2000, Gahleitner, et al. 2004, Jung, et al. 2012, Kang, et al. 2007, King, et al. 2007, Wexler, et al. 2007).

Few authors object, that lateral cephalograms provide sufficient information of bone availability for preoperative planning. Furthermore, lateral cephalograms are made standard in treatment planning and save the patient from additional radiation of CBCT. It was shown, that vertical bone height measured in lateral cephalograms showed 2 mm less bone height, than actually found by probing in the mid-palatal middle and anterior region (Wehrbein, et al. 1999). Jung and co-workers proposed, that the vertical bone height represented on the lateral cephalogram, represents rather the minimum quantity of the bone and coincide with the vertical bone dimension of the parasagittal region. Therefore, indication of CBCT could be limited to only cases with marginal vertical bone quantity (Jung, et al. 2011, 2012b)

The intraosseous length of the body of the Orthosystem® implant is 4.2 mm, however Wehrbein and collaborators showed in an experimental animal study, that only 3 mm of bone height at the insertion site is sufficient for long-time stability under orthodontic load (Wehrbein, et al. 2008). Therefore, minimum afforded vertical bone height might be set to 3 mm. Bernhart and collaborators showed 95% of patients, investigated in their study, had sufficient bone volume for safe insertion of the palatal implant. The most bone height was found 6 to 9 mm posterior the incisive foramen in the mid-sagittal plane. These results correspond with a further study as well (Stockmann, et al. 2009). However, a great variability of bone height in the investigated patients was found. Other studies showed highest mid-palatal bone thickness between the contact points of the right and left maxillary canines and first premolars (Hourfar, et al. 2015), which is close to the findings of another study, where the region of the first premolar was found to be the region with the most mid-palatal bone height (Stockmann, et al. 2009). Männchen and Schätzle, that the insertion of most palatal implants is satisfactorily, when the entry point of the implant is set between first and second premolars perpendicularly to the palatal surface

(Männchen & Schätze 2008). In none of the studies mentioned above, the intramaxillary course of the nasopalatine canal and incisory nerve has been considered as a limiting factor for implantation.

2.4 Complications

All surgical interventions bare the risk of intraoperative or consecutive complications. Besides few studies focusing on specific aspects like pain and discomfort after palatal implantation (Feldmann, et al. 2007), acceptance (Gündüz, et al. 2004) or the impossibility in post-orthodontic removal of the TAD (Nicolas & Bart 2008), only one study (Fäh & Schätzle 2014) retrospectively investigated and documented the spectrum of complications concerning implantation in the palatal region. Fäh and Schätzle reviewed 104 cases of implantation. 25 (24%) cases with surgical complications and adverse patient reactions were documented. In most cases it was lack or primary stability (6,7%) and prolonged pain (6,7%). But also secondary bleeding (5.8%) was often reported. Fewer cases referred to perforation of nasal floor (1.9%), necrotic mucosa anterior of the implant (1.9%) and sensory impairment of the anterior palate (1%). Furthermore 44 explantations were reviewed. Complications, such as impaired wound healing (6.8%), perforation of the nasal floor (2.3%), secondary bleeding (2.3%) and fracture of the implant (2.3%) were documented. All documented complications were of minor severity except for one case, where prolonged sensory impairment of the anterior palate was documented. A small risk of a permanent sensory impairment in the region of the nasopalatine nerve might be a clinical consequence (Schätzle, et al. 2009b).

Concerning post orthodontic implant removal a recent study by Kuhn and co-workers introduced a new protocol for implant removal with a customized non-invasive removal tool. The study showed, that with the established invasive surgery using a hollow screwing cilinder trephine, clinicians were confronted with more post-surgical complications, compared to the new method. Therefore, the authors propose to remove implants with non-invasive customized tools and step back to the surgical method if needed (Kuhn, et al. 2015).

2.5 Morphology of the nasopalatine canal

The nasopalatine canal is located in the median region of the palate, posterior to the central maxillary incisors (Jacobs, et al. 2007). The incisive foramen, located below the incisive papilla, is a funnel-shaped oral opening and lies in the midline of the anterior palate. On its way to the egression on the nasal floor the canal separates into two canaliculi, which open on either side of the nasal septum, known as the foramina of Stenson (Radlanski, et al. 2004). The nasopalatinal canal contains the incisive nerve and the terminal branch of the descending nasopalatine artery, as well as fibrous connective tissue, fat and even small salivary glands (Liang, et al. 2009). Three classifications of anatomic variations of the canal have been proposed. First, a single canal found in 45 of 100 cases. Second two parallel canals were found in 15%. Third a Y-shaped canal, as well as variations of the Y-shaped canal were found in 40 cases out of 100 investigated cases. Mean length of the nasopalatine canal was 10.99 mm (Bornstein, et al. 2011). Another study measured mean length of 12.34 mm and a mean nasopalatine angle of 73.33°. The nasopalatine angle was measured in relation to the tangent line to the nasal floor by measuring the anterior angle. These findings propose, that the morphology of nasopalatine canal is highly variable (Fernández-Alonso, et al. 2014).

2.6 Aim of this study

Owing to the highly variable morphology of the nasopalatine canal and bone volume, insertion in the canal or implant contact to neural tissue may result in lack of primary stability and subsequent failure in osseointegration, to sensory impairment of the premaxilla (Mraiwa, et al. 2004) or enduring pain and consequently lead in all these cases to premature explantation. Up to this day, no study focused on topographical predispositions of the nasopalatine canal as a limiting factor for insertion of mid-palatal TADs. So far, only the palatal bone quantity and quality have been assessed (e.g. (Baumgaertel, et al. 2009, Hourfar, et al. 2015, Jung, et al. 2012, Stockmann, et al. 2009). The specific aim of this study was, therefore, to describe the course of the nasopalatine canal, the adjacent vertical bone quantity, and whether it might differ among vertical facial by evaluating cone beam computed tomography (CBCT) scans.

3. Materials and Methods

3.1 Study population

This retrospective study is based on data collected from CBCT scans performed during examinations at the Department for Oral Surgery and Craniofacial Surgery, Centre for Dental Medicine, University of Zurich, Switzerland, between April 2008 and August 2012. All CBCT images were reviewed (3869 patients), irrespective of the indication for performing the scan. Out of this consecutive sample, data from 398 patients met the following inclusion criteria:

- Both upper and lower jaw completely depicted in the respective field of view (FOV);
- Complete permanent dentition with no deciduous teeth in the buccal segments;
- Teeth in centric relation during CBCT scan;
- No history of maxillofacial injury or surgery;
- No extensive reconstruction of the dentition;
- No syndromes, nor mandibular hypo-/ or hyper dysplasia.

3.2 System and Software

The CBCT images were obtained using the KaVo 3d eXam system (KaVo Dental GmbH, Biberach/Riß, Germany). Patients were sitting with their head positioned parallel to the Frankfurter Horizontal Plane. The resolution of the study images varied from 0.25 mm to 0.4 mm isometric voxel sizes. KaVo eXam Vision Software Version 1.9.3.13 was used to visualize the data. The axial, coronal and sagittal planes were manually adjusted and measurements were taken directly with the measuring tool included in the respective software. Contrast and brightness of the images were optimized manually for every image during the pre-measurement process.

3.3 Software measuring process

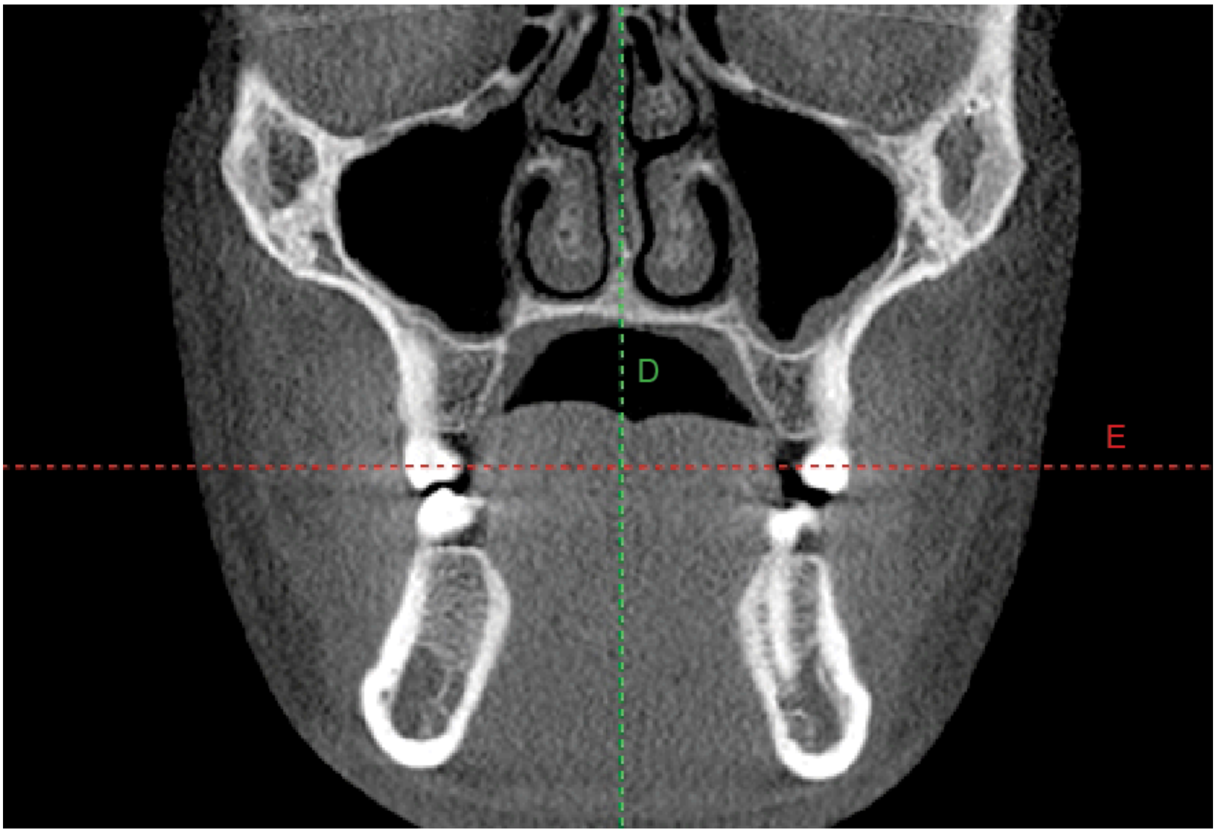

Fig. 2 Coronal scan of a CBCT from a patient included in the study. Line D (green) represents the selected sagittal plane. Line E (red) represents the axial plane.

For further image analysis, a coronal scan was used (Fig. 2) to select the sagittal plane (line D), which passes through the median suture of the hard palate, and the axial plane (line E) that runs through the tooth crowns, where the approximal contacts of the maxillary teeth are located.

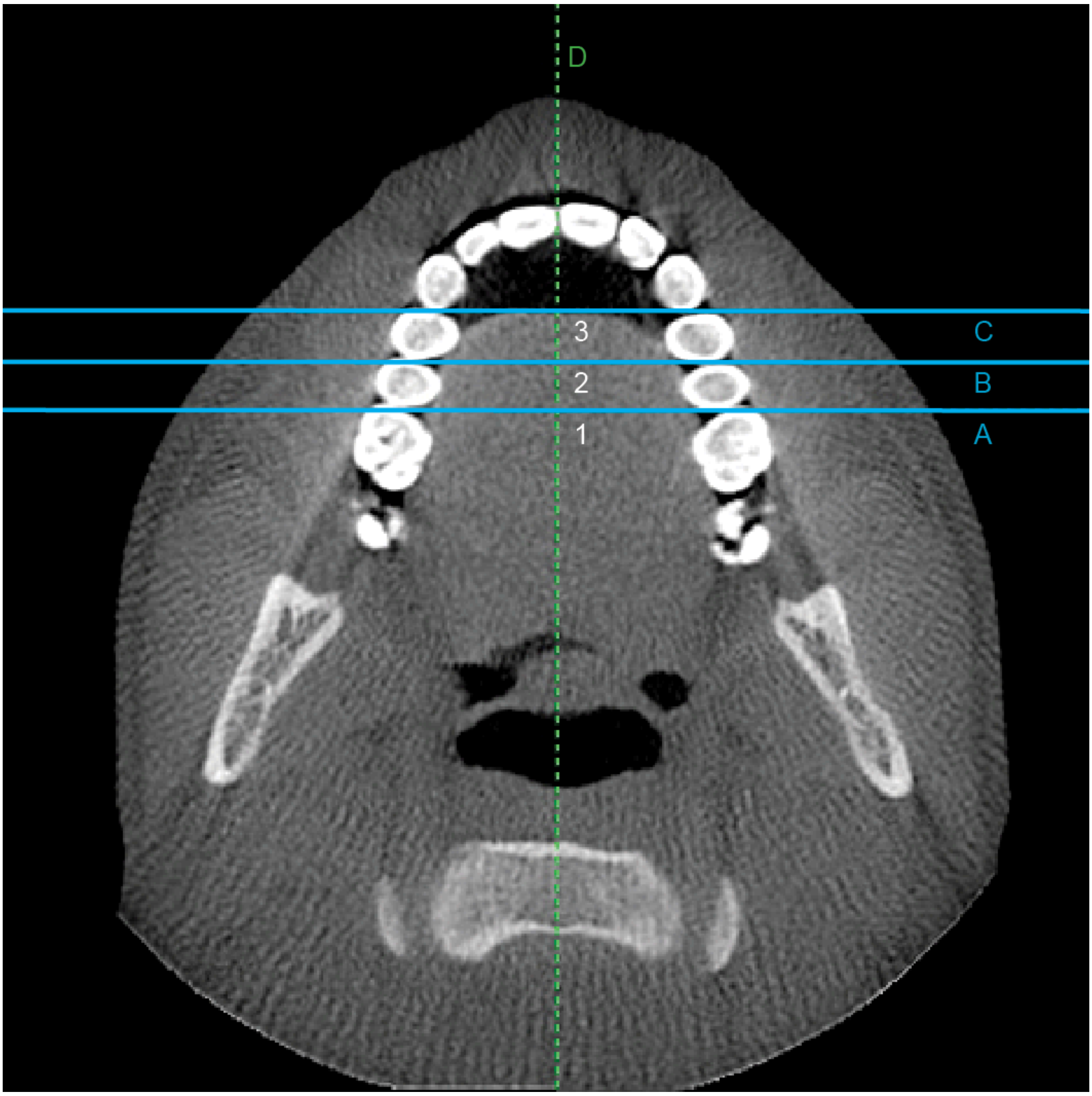

Fig. 3 Axial view exhibiting the selection of the respective coronal planes: coronal plane between first molar and second premolar (line A), between first and second premolar (line B), between canine and first premolar (line C). Measurement points in the median (sagittal plane) identified by the crossings of the coronal planes A, B and C (points 1, 2, and 3).

The selected axial scan was then used to adjust the coronal planes (line A, B, C) to get the three points of measurement, where they cross the sagittal plane (line D) (Fig. 3). If necessary, the images were rotated so that the sagittal planes pass between the central incisors and through the middle of the spine.

The first measurement of the hard palate (point 1) was taken between the first molar and second premolar. The second measurement of the hard palate (point 2) was taken between the second premolar and the first premolar. And the third measurement (point 3) was taken between the first premolar and canine (Fig. 3). If the approximal contacts of the contralateral sides did not correspond to each other on the coronal plane, the approximal contacts of the left side were chosen to determine the measurement points.

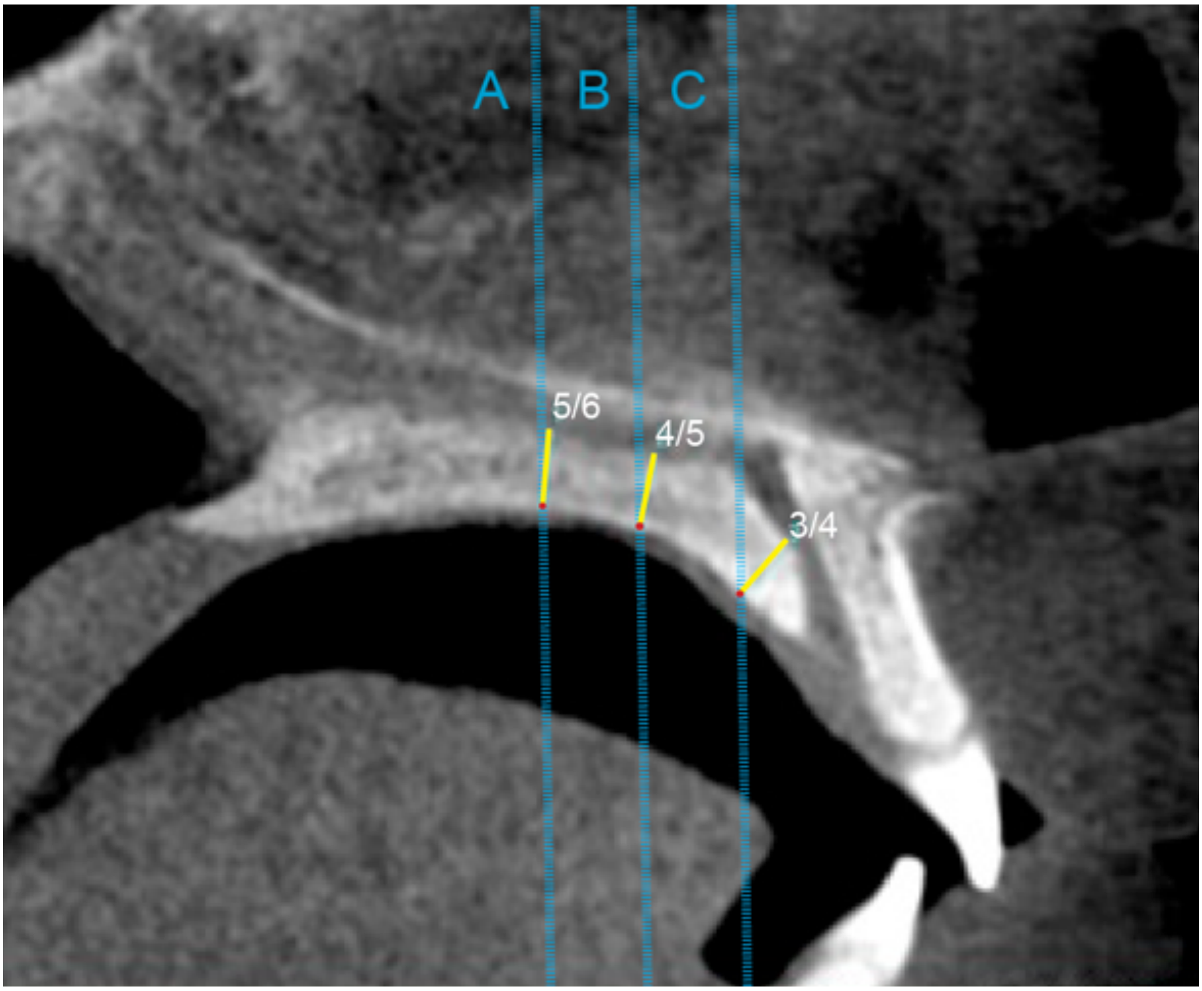

Fig. 4 Sagittal view of the hard palate with the three measurement points (ContPnt 5/6, 4/5, 4/3) as identified by the crossings of the coronal planes (A, B, C), respectively.

The linear measurements were taken on the respective sagittal view (Fig. 4). The measurements were taken using the included measuring tool for distances provided by the software (eXam Vision). The crossings of the coronal planes A, B and C through the hard palate on the axial scans determined the measurement points. The distances in mm were taken perpendicular from the oral surface of the cortical bone to the nasal surface or nasopalatine canal critical surface of the hard palate, respectively.

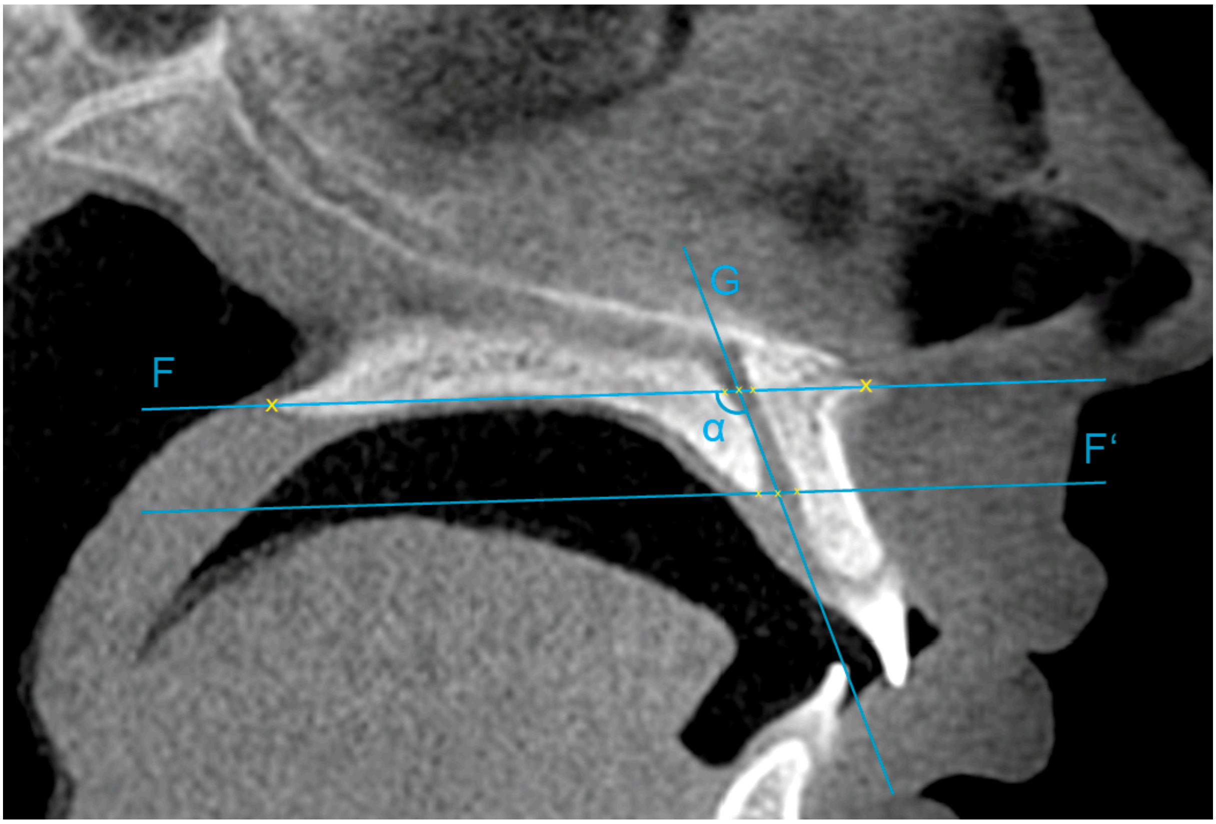

Fig. 5 Representative illustration of the measured angle (α) representing the angulation of the nasopalatine canal (line G) compared to the base of the upper jaw. Line F is drawn through the anterior and posterior spine of the palate.

For the measurement of the inclination of the nasopalatine canal (Fig. 5) with regard to the maxillary jaw base as determined by the anterior and the posterior nasal spine, a line F was manually drawn on a screen-print (HP Laser Jet 500 Colour M551) using a sharp pencil connecting the respective landmarks. A second line F’ was drawn parallel to line F at the opening of the nasopalatine canal, where the incisive nerve emerges from the nasopalatine canal. Where line F crosses the nasopalatine canal, the posterior and the anterior bony aspect of the canal were registered and half of the distance was marked. This was done similarly at the oral opening of the canal. Through these two points, a line G was drawn. The intersection of line F and line G was taken for the measurement of angle (α) representing the angulation of the nasopalatine canal with regards to the maxillary jaw base (Fig. 5).

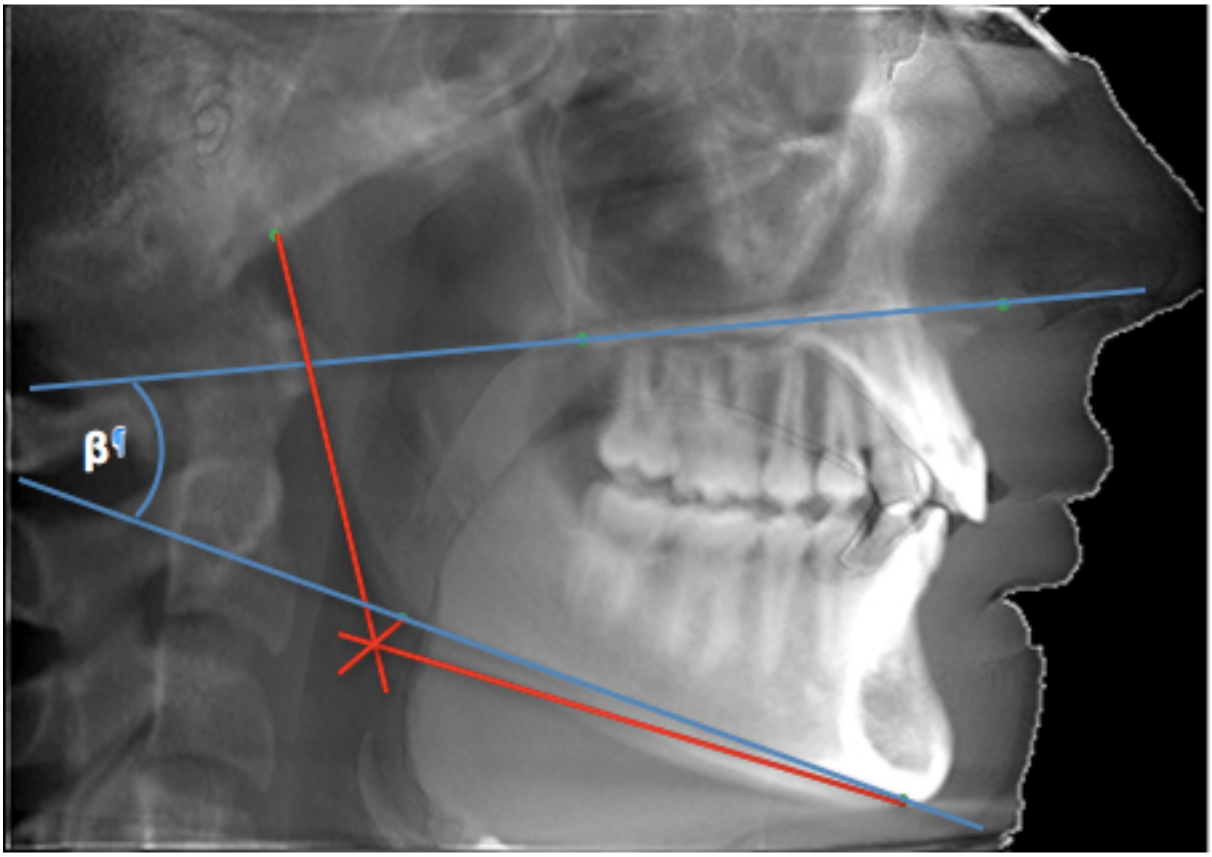

Fig. 6 Lateral cephalogram calculated by the eXam Vision software illustrating the jaw base divergence.

Lateral cephalograms, as commonly used for orthodontic treatment planning, were calculated by the eXam Vision software using the data from the CBCT scans (Fig. 6), and then printed. The jaw divergence (β) was obtained by the intersection of maxillary base line, determined by landmarks of anterior and posterior nasal spine and mandibular base line represented by the landmarks Gonion (Go) and Menton (Me). The first (Go) is derived by bisecting the angle formed by the junction of the ramal and mandibular planes (Moyers 1973), the latter (Me) is defined as the lowermost point on the symphysis in the median plane (Broadbent, et al. 1975). All drawings were done by an experienced senior specialist in orthodontics.

In order to assess the intraobserver reliability (repeatability), all measurements of 20 randomly chosen radiological measurement data sets were repeated 2 months apart.

3.4 Statistical Analysis

A commercially available software package (IBM SPSS version 20, Armonk, New York, U.S.A.) was used for all statistical analyses. To determine intraobserver reliability (repeatability), the intraclass correlation coefficient (ICC) for absolute agreement based on a one-way random effects analysis of variance (ANOVA) was calculated, which was done for each variable separately. The variables were descriptively evaluated, box-and-whisker plots were generated for the distances and normal distribution was tested with a Kolmogorov-Smirnov test. None of the variables followed normal distribution ($p<0.05$), except angle α (p: 0.066), hence non-parametric statistical testing was performed, using a two-sided Spearmen's rho to measure the statistical dependence between the variables. Scatter-plots between the variables were generated with linear best fit lines to illustrate the association between the variables. P-values smaller than 0.05 were considered statistically significant.

4. Results

The results of the repeatability analysis are given in Table 1. All intraclass correlation coefficients are above 0.9, demonstrating very satisfactory results for all variables.

ICC	**N**	**ICC**	**95% CI**
β (°)	20	0.991	0.977 - 0.996
α (°)	20	0.995	0.988 – 0.998
ContPnt 5/6 (mm)	20	0.985	0.963 – 0.994
ContPnt 4/5 (mm)	18*	0.982	0.952 – 0.993*
ContPnt 3/4 (mm)	9*	0.907	0.620 – 0.979*

*Contact Point 4/5 is missing in 2 cases, due to extracted premolars during orthodontic treatment. In 11 cases, measurement could not be taken due to direct insertion into the incisive foramen at contact point 3/4.

Table 1: Values of the Intraclass Correlation Coefficients (ICC) to determine repeatability of the measurements.

The demographic descriptive values of the evaluated sample are summarized in Table 2, establishing that no apparent gender-related differences exist concerning age distribution.

	Overall N=398	Females N=197	Males N=201
Mean age (y)	26.6	26.7	26.5
Min (y)	9.4	9.4	10.7
Max (y)	63.0	49.7	63.0
SD (y)	9.1	8.7	9.5

Table 2: Descriptives of the sample regarding gender and age distribution.

Table 3 visualizes the measured variables including testing for normal distribution. Due to a lack of normal distribution, further analyses were done using non-parametric testing. As some of the patients had extractions, not all premolars were present and therefore the numbers of ContPnt 5/6, 4/5 and 3/4 are not consistent**.** The respective measured vertical bone distances listed in the table are also given as box-and-whisker plots (Fig. 7). The mean value for the first measurement of the hard palate (point 1) between the first molar and second premolar is 4.09 mm. The mean vertical bone available between the second premolar and the first premolar (point 2) is 5.22 mm, and the measurement between the first premolar and canine (point 3) exhibits a mean value of 2.88 mm.

	N	Mean	Median	1.SD	IQR	Min	Max	Normal distribution
β (°)	398	26.65	27.0	5.83	8.0	13	45	No
α (°)	398	103.26	103.0	8.20	10.0	79	131	Yes
ContPnt 5/6 (mm)	398	4.09	4.0	1.55	2.35	0.80	8.94	No
ContPnt 4/5 (mm)	378	5.22	5.20	1.66	2.13	1.79	10.25	No
ContPnt 3/4 (mm)	226	3.14	2.88	1.41	2.00	0.57	7.38	No

Table 3: Descriptives of the variables; normal distribution tested with Kolmogorov-Smirnov test at significance level p = 0.05.

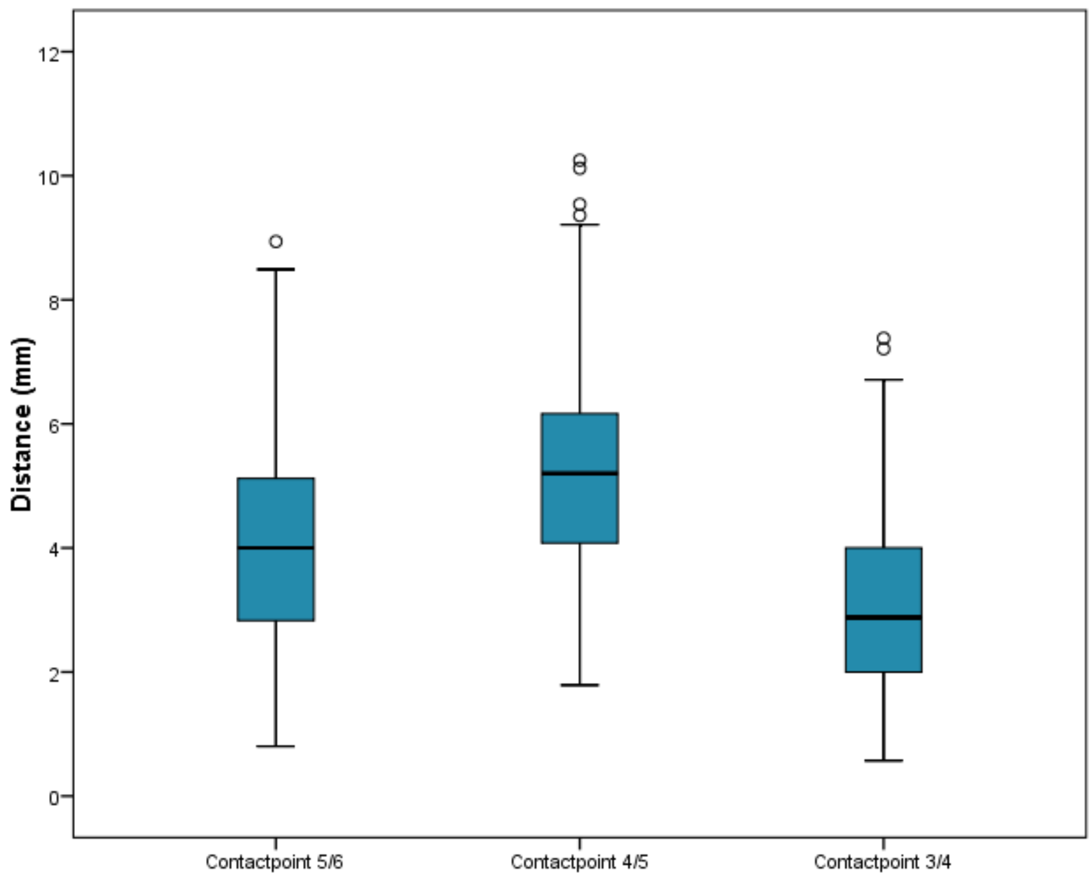

Fig. 7: Box-and-whisker plots for the measured distances (vertical bone available).

In the majority of the cases (56.1%), vertical bone volume > 4mm in the region 5/6 (first molar and second premolar; Fig. 8) was found.

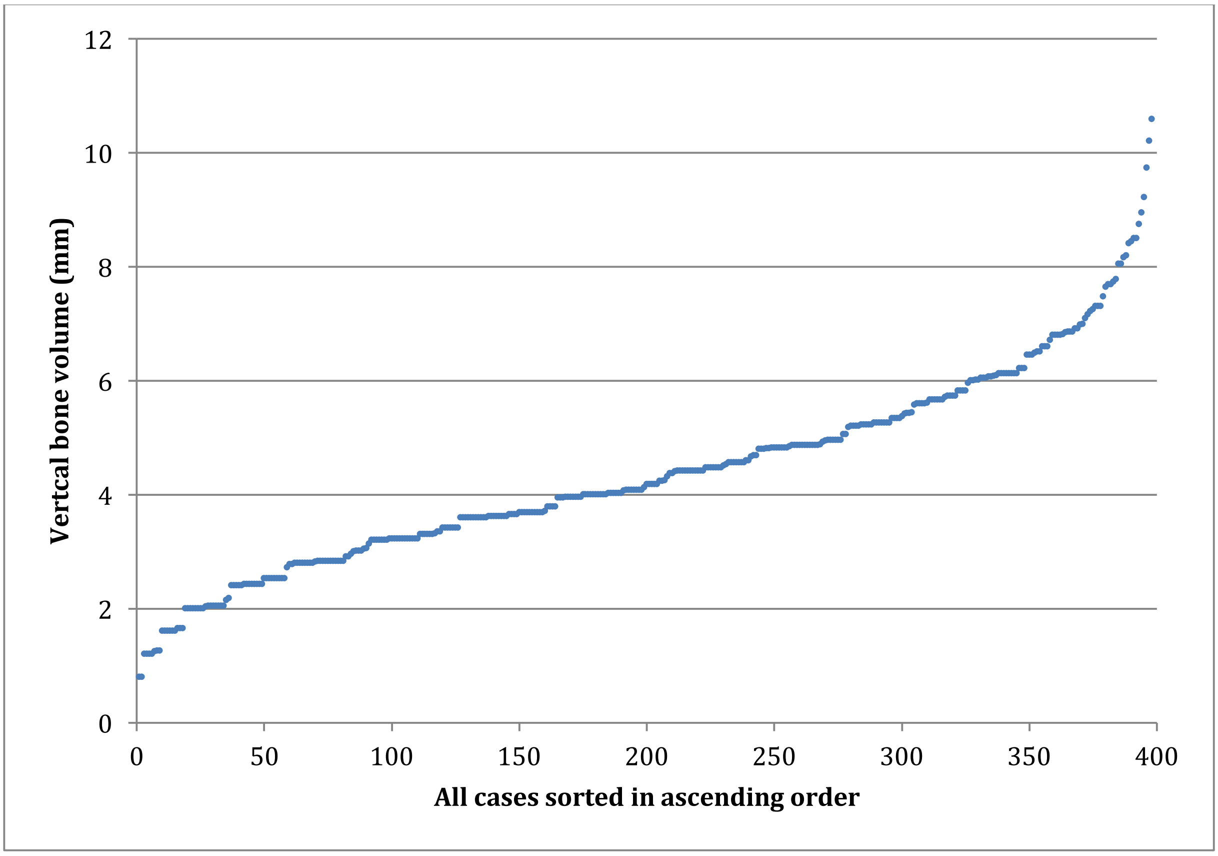

Fig. 8: All measurements for vertical bone volume in the region 5/6 (first molar and second premolar; n = 398).

In order to assess different associations between the measured variables, correlation analyses were performed. In a first step, the correlation was sought between the jaw divergence with the other variables (Table 4), and subsequently a correlation analysis was done to establish potential association between the angulation of the canal and the bony measurements (Table 5).

	α	**ContPnt 5/6**	**ContPnt 4/5**	**ContPnt 3/4**
N	398	398	378	226
Corr. coefficient	-.219	0.013	0.008	0.024
p-value	**<0.001**	0.793	0.880	0.715

Table 4: Correlations between β and the other variables (bold lettering marks statistically significant findings).

	ContPnt 5/6	**ContPnt 4/5**	**ContPnt 3/4**
N	398	378	226
Corr. coefficient	-0.061	-0.176	-0.262
p-value	0.228	**0.001**	**<0.001**

Table 5: Correlations between α and the bone measurements (bold lettering marks statistically significant findings).

It is apparent that a statistically significant, but weak negative correlation exists between both angle measurements (Table 4), indicating that the greater the divergence between the jaws, the steeper the canal angulation will be. In order to illustrate the weak association between the two angulations, α was plotted against β, and a regression line was drawn (Fig. 9).

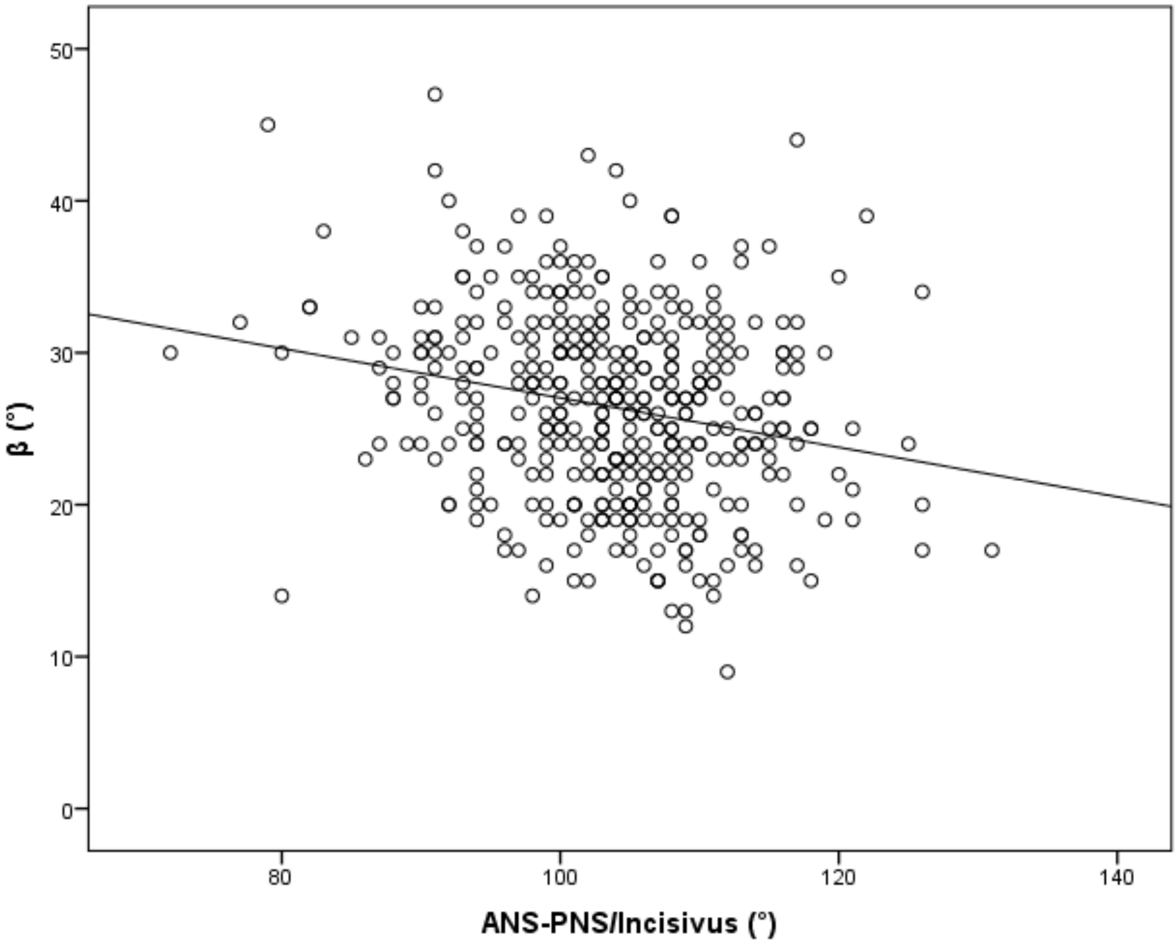

Fig. 9: Scatter plot including regression line exhibiting the weak association between the two angles (α and β).

Furthermore, statistically significant negative correlations were established between the canal angulation and bone measurements 4/5 and 3/4, respectively, demonstrating that the more obtuse the angle, the shorter these distances. It is noteworthy to pinpoint the lack of this association with measurement 5/6.

5. Discussion

All surgical interventions bare the risk of intra- or postoperative complications. This is also especially true for dental implant placement, where it has been reported that three quarters of all neurosensory disturbances following implant insertion are found to be of permanent nature (Jacobs, et al. 2014, Libersa, et al. 2007). Only one study assessed the spectrum of possible surgical complications or risks during palatal implant insertion or removal (Fäh & Schätzle 2014). A small risk of a permanent sensory impairment is one important clinical consequence (Fäh & Schätzle 2014, Schätzle, et al. 2009b). So far, only the palatal bone quantity and quality have been assessed with regards to preoperative radiographic diagnostics of palatal implants (e.g. (Baumgaertel, et al. 2009, Hourfar, et al. 2015, Jung, et al. 2012, Stockmann, et al. 2009). No study has focused on topographical predispositions of the nasopalatine canal as a potential limiting factor for insertion of mid-palatal TADs. The aim of this study using CBCT data sets was therefore to describe the course of the nasopalatinal canal, the adjacent vertical bone quantity, and whether these values might differ among different vertical facial types.

As dental CT or CBCT of the alveolar process are well established for the evaluation of the alveolar bone volume before implant placement (Bornstein, et al. 2014, Lindh, et al. 1995), they might also be used to assess the vertical bone volume of the hard palate prior to TAD placement. A number of authors recommend the routine use of 3D imaging for preoperative diagnosis and planning of skeletal TAD, especially for palatal implants (Bantleon, et al. 2002, Bernhart, et al. 2000, Gahleitner, et al. 2004, Kang, et al. 2007, King, et al. 2007, Wexler, et al. 2007). However, this recommendation is largely based on theoretical considerations due to potential complications such as perforation to the nasal floor or damage to the nasopalatine nerve (Jung, et al. 2012). The greatest mean thickness was identified to be about 6–9 mm posterior to the incisal foramen in the mid-sagittal plane (Bernhart, et al. 2000). If the necessary bone volume for an orthodontic implant installation is defined as 4 mm or more, 95% of the patients investigated had sufficient vertical bone volume for accommodating palatal implants with a length of 4 mm (Bernhart, et al. 2000). This finding has been also reported by another study (Schiel, et al. 1996). It must be considered, however, that the patients in the current investigation showed a great range of variation of vertical bone volume posterior to the incisal foramen (ranging 0.57 to 10.25 mm, Table 3), rendering a detailed preoperative diagnostic process necessary in order to avoid potential perforation of the floor of the nose. Yet, in the majority of the cases (56.1%), vertical bone volume was sufficient (> 4 mm) in the region 5/6 (first molar and second premolar) to warrant the safe placement of TADs (see also Fig. 8).

Insisting on obtaining precise information for the intended implant sites before placing palatal implants using lateral cephalograms rather than CT examination was proposed by Wehrbein and colleagues (1999). Since the former are used for orthodontic diagnosis and treatment planning, this would spare patients from additional radiation exposure. It was suggested that the vertical bone heights in the anterior and middle thirds of the hard palate were at least 2 mm greater than identified on lateral cephalograms (Wehrbein, et al. 1999). A safety level of at least 2 mm is therefore recommended when planning treatment on the basis of lateral cephalograms. The vertical dimension on lateral cephalometry reflects the minimum quantity of bone, which is usually seen in the parasagittal plane, and not the maximum quantity of vertical bone in the median plane. Therefore, preoperative CT or cone-beam computed tomography (CBCT) is only indicated when lateral cephalometry reveals a marginal quantity of bone (Jung, et al. 2011, 2012b).

Currently, there is not sufficient data available about the course of the nasopalatine canal in the anterior maxilla, and its possibly underlying relation to the skeletal pattern. In a retrospective study assessing complications associated with the surgical insertion and removal of palatal implants, one patient suffered from a prolonged hypoaesthesia of the anterior palate (Fäh & Schätzle 2014). This may have been due to a direct injury of the incisive nerve or its compression. The difficulties for implant placement in the anterior maxilla in context with the nasopalatine canal are known to oral surgeons and different studies have already investigated the anatomical morphologies of the nasopalatine canal (Bornstein, et al. 2011, Fernández-Alonso, et al. 2014, Mraiwa, et al. 2004). Mraiwa concluded that the nasopalatine canal may show important anatomical variations, and therefore a careful pre-operative observation is required. Variable procedures have been presented to deal with the nasopalatine canal when inserting dental implants ranging from enucleation, application of autogenous cancellous bone harvested from the chin, and subsequent implant insertion (Rosenquist & Nyström 1992) to more conservative approaches trying to spare the neurovascular structure of the nasopalatine canal by combining horizontal and vertical bone grafting with a lateralization of the vital structures in the region of the incisive foramen only (Urban, et al. 2015).

It is interesting to note that based on the findings of the present study, the morphology of the nasopalatine canal varies in the canine and premolar region in relation to the vertical skeletal pattern. Patients with a hypodivergent skeletal pattern showed a significantly shallower inclination then patients with a hyperdivergent skeletal pattern. This points to the fact that the vertical bone volume is reduced in patients with a hypodivergent skeletal pattern. Despite the statistical significance, this might not be clinically significant. Overall, the area of the first and second maxillary premolar is the most favourable overall anatomic area for palatal TAD placement. However, with placement at the canine and first premolar region, it is important to consider the potential proximity to the nasopalatine canal. Although the incisive foramen is topographically closely related to the incisive papilla, the actual canal extends superiorly and posteriorly with a negative correlation to the vertical facial skeletal pattern. If clinically or radiographically indicated, paramedian implant insertion in this anterior region might be recommended.

6. Conclusions

In conclusion, orthodontic palatal temporary anchorage devices with a length of 4 mm might be inserted at the level of the contact point of the first and second premolar or more distally. Generally, the vertical bone volume is sufficient and bares only a small risk for permanent neuro-sensory impairment due to damage of the incisive nerve. Nevertheless, it must be kept in mind that the course is significantly negatively correlated with the vertical skeletal facial pattern pointing to the fact that in hypodivergent patients the TAD might be placed in a more distal or paramedian region.

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